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THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

NOVEMBER, 1953

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

NICKEL

Removal of Restrictions on Use of Nickel

'Nickel Restrictions Lifted.' *Times*, Nov. 6, 1953.

The following notices have been issued with regard to rescinding of prohibitions on the use of nickel imposed by the Council of the Organization for European Economic Co-operation in May, 1952:—

'The Council of the Organization for European Economic Co-operation has decided to suspend forthwith the common list of restrictions in the use of nickel, nickel alloys, and nickel-plating and the application of measures limiting the use of nickel in case-hardening and constructional steels. Member countries are at liberty to decide whether to suspend or maintain restrictions on the national level in accordance with their own requirements.

The announcement says that the O.E.E.C. iron and steel and non-ferrous metals committees will follow the supply position for nickel closely and make any necessary new proposals to the Council for the restoration of restrictive measures, or for their final repeal.'

'The Board of Trade and the Ministry of Supply announce that all restrictions on the use of nickel are being removed as from November 6th, 1953. The directions restricting the use of nickel in the manufacture of alloy steels have also been withdrawn.'

See *Statutory Instrument*, 1953, No. 1605, *Board of Trade Nickel Prohibited Uses Revocation Order*, and the corresponding *Minister of Supply Revocation Order*, 1953, No. 1607.

Effect of Alloying Elements on Creep of Nickel

T. H. HAZLETT and E. R. PARKER: 'Effect of Some Solid-Solution Alloying Elements on the Creep Parameters of Nickel.' *Amer. Soc. Metals, Preprint 39*, Oct., 1953; 15 pp.

This paper describes constant-stress experiments on four series of solid-solution nickel-base alloys, of the compositions shown below:—

Nickel–Iron: containing 2·55, 4·94 and 9·77 at. per cent. iron.
Nickel–Cobalt: containing 2·43, 4·60 and 8·69 at. per cent. cobalt.
Nickel–Titanium: containing 0·25, 1·0 and 2·0 at. per cent. titanium.
Nickel–Tungsten: containing 0·5 and 1·0 at. per cent. tungsten.

Creep tests at 700°C. were made in single-specimen creep units previously described by the authors, under conditions of constant stress (rather than constant load), controlled within less than ½ per cent.

The results of the tests have been correlated by means of a time-temperature relationship recently proposed by the authors:—

$$\varepsilon - \varepsilon_o = At^b$$

Where ε = total true strain.
ε_o = instantaneous strain at moment of loading.
t = time.
A, b = constants.

The constant-stress creep-curve data obtained on the alloys of the four groups mentioned satisfy this creep equation, and it is shown that the three creep parameters involved in the equation vary in a regular manner with the solid-solution alloy content.

The results on the individual alloys are illustrated with many graphs, and the influence of alloy content, on the respective variables involved in the equation, is presented in summary graphical form.

B.S. Specification for Nickel Anodes and Nickel Salts

See abstract on p. 184.

Energy Stored in Deformed Nickel: Observations on Release

L. M. CLAREBROUGH, M. E. HARGREAVES and G. W. WEST: 'The Release of Energy Stored in Deformed Nickel.' *Philosophical Mag.*, 7th Ser., 1953, vol. 44, Aug., pp. 913–15.

Determinations made, by various investigators, of the energy stored during deformation of pure copper have shown some inconsistencies, and the data obtained have suggested that a portion of the energy stored may be released at room temperature.

In view of the above findings, the present authors have made measurements of energy stored during deformation of nickel, and have correlated such measurements with changes in hardness and electrical resistivity. The determinations were made on bars of nickel of commercial purity, deformed in torsion. Specimens used for hardness measurements were quenched from various temperatures up to 750°C.; resistivity was determined during heating. The most striking feature of the results reported is that approximately 40 per cent. of the energy stored during deformation is released before any reduction in hardness occurs, and this release is associated with the disappearance of the majority of the increase in resistivity caused by deformation. This observation is discussed in relation to suggestions which have been made that vacancies generated during deformation are the main cause of the accompanying increase in electrical resistivity. A fuller account of this work is to be published later.

Barkhausen Effect in Single Crystals of Nickel

R. S. TEBBLE and V. L. NEWHOUSE: 'The Barkhausen Effect in Single Crystals.' *Proc. Physical Soc.*, Sect. B, 1953, vol. 66, Aug. 1, pp. 633–41.

Measurements have been made on the Barkhausen effect in single crystals of silicon-iron and of nickel. The results of the work, done on small single crystals, have demonstrated that the magnitude of the Barkhausen effect is strongly shape-dependent. It is shown that the demagnetizing factor of the specimen is an important variable; the effect of a high demagnetizing factor is to reduce the magnitude of the Barkhausen effect and to produce a corresponding increase in the contribution of the reversible magnetization processes.

Spectrographic Analysis of Nickel

W. NIELSCH: 'Modern Excitation Methods for the Spectrographic Analysis of Nickel.' *Metall*, 1953, vol. 7, July, pp. 513–16.

The author gives details of procedure for qualitative determination of traces of lead, zinc, tin, and silver, and for quantitative estimation of magnesium, manganese, iron, and cobalt.

ELECTRODEPOSITION AND OTHER COATING METHODS

B.S. Specification for Nickel Anodes and Nickel Salts

BRIT. STANDARDS INSTN.: 'Nickel Anodes and Nickel Salts for Electroplating.' *B.S. 558* and *564*: 1953.

Anodes

The chemical composition limits specified for anodes are as follows:—

Nickel (or nickel+cobalt) not less than 99·00 per cent., the percentage of nickel being not less than 98·50.

The amount of individual impurities present in the anodes is not to exceed the following limits:—

			% max.
Iron, calculated as	Fe	.. ..	0·75
Lead, „	Pb	.. ..	0·10
Copper, „	Cu	.. ..	0·25
Silicon, „	Si	.. ..	0·10
Manganese, „	Mn	.. ..	0·10
Carbon, „	C	.. ..	0·30
Zinc, „	Zn	.. ..	0·01

Total impurities shall in no case exceed 1·00 per cent.

The methods by which cobalt and the impurity elements are to be estimated are laid down in appendices to the specification.

Nickel Salts

(1) *Nickel Ammonium Sulphate*

The nickel ammonium sulphate is to be in either crystal or powder form, and its composition is to correspond approximately to the formula $NiSO_4.6H_2O$.

The material is to contain not less than 14·6 per cent. of nickel and cobalt (calculated as metal), the percentage of cobalt being not more than 1·0.

Impurities are not to exceed the following limits:—

			% max.
Iron, calculated as	Fe	.. ..	0·05
Lead, „	Pb	.. ..	0·05
Copper, „	Cu	.. ..	0·02
Zinc, „	Zn	.. ..	0·01

Total matter insoluble in water is not to exceed 0·20 per cent. pH value of a solution of the salt in water (determined by a method laid down in the appendix) is not to be less than 2·0.

(2) *Nickel Sulphate*

The material shall be in crystal or powder form, and may be a mixture of hydrates, but the composition is required to fall between the limits represented by the formulae $NiSO_4.6H_2O$ and $NiSO_4.7H_2O$.

The salt is to contain not less than 21·8 per cent. of nickel and cobalt (calculated as metal), with the cobalt not more than 1·0 per cent. Impurities are not to exceed the following limits:—

			% max.
Iron, calculated as	Fe	.. ..	0·02
Lead, „	Pb	.. ..	0·01
Copper, „	Cu	.. ..	0·01
Zinc, „	Zn	.. ..	0·01
Insoluble matter	} as for nickel ammonium sulphate		
pH			

(3) *Nickel Chloride*

The chloride is to be in crystal or powder form, of composition approximating to the formula $NiCl_2.6H_2O$. It is to contain not less than 23 per cent. of nickel and cobalt (calculated as metal), the cobalt being not more than 1·0 per cent. Impurities are not to exceed the following limits:—

			% max.
Iron, calculated as	Fe	.. ..	0·05
Lead, „	Pb	.. ..	0·01
Copper, „	Cu	.. ..	0·02
Zinc, „	Zn	.. ..	0·01
Insoluble matter	} as for nickel ammonium sulphate		
pH			

Methods for determination of insoluble matter, lead, copper, iron, nickel, cobalt, and zinc in nickel salts are detailed in the appendices, and procedure for determination of acidity is also given.

B.S. Specification for Electrodeposited Coatings of Nickel and Chromium

BRIT. STANDARDS INSTN.: 'Electroplated Coatings of Nickel and Chromium.' *B.S. 1224*: 1953.

The British Standards Institution has recently issued a revision of the above specification, which was originally published in 1945. The principal reason for revision was that the original schedule did not fully meet the requirements of the motor-car industry.

In the new edition provision has been made for a

thicker coating of nickel on steel (not less than 0·0012 in. nickel or not less than 0·003 in. copper+0·0010 in. nickel), and for coatings on zinc alloys. The specification now covers (*a*) nickel coatings on steel, copper, copper-base alloys, zinc-base alloys, and aluminium and its alloys, and (*b*) chromium coatings on nickel undercoats deposited according to the specification, and on articles of stainless steel and stainless iron.

The Standard has been drawn up with a view to ensuring the qualities essential in the coatings covered, but it is realized that it is impossible, at the present time, to specify completely every factor affecting the service performance of an electrodeposited coating. An important feature of the specification is the requirement for minimum thickness on significant surfaces, and particular attention is also directed to the effect of the contour of plated parts.

In addition to the tables showing minimum local thickness required in coatings on the various types of basis metal, details are given of approved methods for determination of local thickness and adhesion, and for the salt-spray test. Procedure for determining the specified presence of 0·00001 in. of chromium is also given. Heat-treatments which may be applied to nickel- and nickel+chromium-plated parts on steel are described.

Removal of Restrictions on Use of Nickel

See abstract on p. 183.

Electrodeposition: Review of Recent Developments

U.S. NAT. BUR. STANDARDS: 'Electrodeposition Research.' *N.B.S.* Circular 529, May, 1953; 129 pp.

Report of proceedings at the N.B.S. Semicentennial Symposium on Electrodeposition Research, held at the National Bureau of Standards in December, 1951.

The first part of the Conference was devoted to a survey of the current stage of development of electrodeposition in various parts of the world, with some account of research which has been carried out in recent years in the respective countries. Individual contributions are listed below.

G. E. GARDAM: 'Research on Electrodeposition in Great Britain,' pp. 1–13; disc., p. 13.

Account of the contribution of academic, Governmental and industrial laboratories to recent progress.

J. SALAUZE: 'Electroplating Research in France,' pp. 15–21; disc., pp. 21–2.

P. BAEYENS: 'Electroplating Research in Germany, Belgium and Holland,' pp. 23–6.

The second section of the proceedings covered reports of work on electrodeposition and related subjects at various U.S. centres of research:—

W. BLUM: 'Electrodeposition Research at the National Bureau of Standards,' pp. 27–8.

A highly condensed list of the subjects on which research has recently been carried out; for fuller details reference should be made to the Bureau's Technical News Bulletin, of December, 1951.

C. L. FAUST: 'Electrodeposition Research at Battelle Memorial Institute,' pp. 29–34; disc., pp. 34–5.

A list showing the scope of electrodeposition research at Battelle, followed by short articles on specific subjects, e.g., electrodeposited alloys as protective finishes for aircraft parts, the mechanism of the entry of hydrogen into metals, and electroforming of aluminium.

J. E. STARECK: 'Electrodeposition Research at United Chromium Incorporated' (abstract), p. 36.

O. C. RALSTON: 'Electrodeposition Research at the Bureau of Mines,' pp. 37–9; disc., pp. 39–40.

Summary of some contributions of electrodeposition to extractive metallurgy.

W. H. COLNER: 'Electrodeposition Research in Progress at Armour Research Foundation,' pp. 41–5; disc., pp. 45–6.

Subjects to which reference is made include electrodeposition on titanium, silver plating of wave guides, and the deposition of magnetic nickel–cobalt alloy in connection with research on magnetic recording.

G. W. JERNSTEDT: 'Electrodeposition Research of Westinghouse Electric Corporation,' pp. 47–50; disc., pp. 50–2.

The paper deals with the periodic-reverse-current (P.R.P.) process developed in the Westinghouse laboratories.

K. G. COMPTON and R. A. EHRHARDT: 'Brass Plating,' pp. 53–4; disc., p. 55.

Account of work in the Bell Telephone Laboratories, in development of brass-plating solutions giving minimum variation of composition with change in current density.

R. A. SCHAEFER: 'Electroplating in the Sleeve-Bearing Industry,' pp. 57–62; disc., pp. 62–3.

W. R. MEYER: 'Research at Enthone, Inc., on Metal Finishing,' pp. 65–8; disc., p. 68.

Brief notes on conversion coatings; blackening and colouring of metals; chemical-displacement coatings; oxide coatings on metals; selective dissolution of metals; detergents, cleaners, etc.; stripping of organic coatings; cyanide-free electroplating solutions, with special reference to nickel-sulphamate baths.

M. R. CALDWELL, L. B. SPERRY, L. M. MORSE and K. H. DELONG: 'Corrosion-Resistance of Copper-, Nickel- and Chromium-Plated Zinc-, Aluminium- and Magnesium-base Die Castings,' pp. 69–71; disc., pp. 71–2.

Condensed version of paper published in *Plating*, 1952, vol. 39, pp. 142–8, 159–63; see *Nickel Bulletin*, 1952, vol. 25, No. 4, pp. 97–8.

E. R. BOWERMAN: 'Plating Research at Sylvania Electric Products,' p. 72.

Very brief note on research in hand on cleaning methods, and on zinc–tin alloy plating.

E. J. SERFASS: 'Determination of Impurities in Electroplating Baths,' pp. 73–9.

Summary of work under A.E.S. Research Project No. 2. The major reports issued in connexion with

this research have been published in *Plating*, and have been reviewed in *The Nickel Bulletin* at the times of publication.

D. T. EWING, J. K. WERNER and A. BROUWER: 'Effects of Impurities in Plating Solutions,' pp. 81–8; disc., pp. 88–9.

Summary of work under A.E.S. Research Project No. 5, which has been reviewed in *The Nickel Bulletin* at the time of publication of individual reports over the years 1946–1950.

N. THON: 'Porosity in Perspective,' pp. 91–4.

Note based on experience gained and conclusions drawn during work under A.E.S. Research Project No. 6, of which the author is in charge.

F. OGBURN and A. BENDERLY: 'Correlation of Gas Permeability of Electrodeposits with their Weathering Behaviour,' pp. 95–6; disc., pp. 96–9.

As an extension of A.E.S. Research Project No. 6, on permeability of electrodeposits, a further Project (No. 13) has been initiated, to ascertain to what extent a newly developed method of measuring gas-permeability of detached electrodeposited foils can be applied to prediction of the performance of adherent electrodeposits in service. To date, the work has been concerned only with nickel foils produced from a typical Watts bath.

A. BRENNER: 'Properties of Electrodeposited Nickel,' pp. 101–11; disc., pp. 111–12.

Condensed version of the very comprehensive report issued, in 1952, under the aegis of A.E.S. Research Project No. 9; see *Plating*, 1952, vol. 39, pp. 865–94, 899–927, 933; *Nickel Bulletin*, 1952, vol. 25, No. 11, p. 258.

B. F. DODGE, C. A. WALKER and W. ZABBAN: 'Disposal of Cyanide Wastes from Plating Operations,' pp. 113–19; disc., pp. 119–20.

Report of work done under A.E.S. Research Project No. 10.

J. KRONSBEIN: 'Current and Metal Distribution in Electrodeposition,' pp. 121–4.

The notes are based mainly on certain theoretical phases of A.E.S. Research Project No. 11 which are not scheduled for publication in *Plating*, but which appeared worthy of discussion at the conference.

H. B. LINFORD: 'A New Degreasing Evaluation Test: the Atomizer Test,' pp. 125–8; disc., pp. 128–9.

This note, based on work under A.E.S. Research Project No. 12, is supported by various papers published in *Plating*. Reference has already been made in *The Nickel Bulletin* to these reports.

Nickel Plating of Aluminium

R. ORE: 'Practical Aspect of the Plating of Aluminium Hollow-Ware.' *Bull. Inst. Metal Finishing*, 1953, vol. 3, Autumn, pp. 163–72: *Trans. Inst. Metal Finishing*, 1953, vol. 29.

Following a paper by WALLBANK on commercial nickel-plating of aluminium (*Jnl. Electrodepositors' Tech. Soc.*, 1952, vol. 28; see *Nickel Bulletin*, 1952, vol. 25, No. 6, p. 148), the author of the present paper describes a method of broadly similar nature, but differing in certain details, to which particular attention is drawn. The paper describes the cycle of operations used in a shop engaged in plating of aluminium teapots and other articles of table- and kitchen-ware.

After preliminary mopping the work is degreased in trichlorethylene, and then highly coloured by means of a basil mop, using dry lime. Alternatively, a swansdown mop may be used. Jigging is an important feature; jigs developed for teapots and covers are illustrated. The sequence of operations is as follows:—

Cleaning

Electrolytic cleaning in solution containing (oz./gall.; g./L.): caustic soda 4·5 (28); sodium cyanide 4·5 (28): sodium carbonate 2·25 (14).

Swilling in running water.

Acid etching I: 5 per cent. v./v. hydrofluoric acid; room temperature; 5 seconds; rubber-lined iron tank.

Swilling in running water.

Acid etching II: 50 per cent. v./v. nitric acid; room temperature; 5 seconds; earthenware tank.

Swilling in running water

After the final swilling the articles should be plated with the least possible delay. The sequence of operations is:—

Plating

Zinc Plating

	oz./gall.	g./L.
Zinc chloride	0·4	2·5
Potassium cyanide	0·2	1·25
Caustic soda	4·0	25·0
Ammonia (0·880)	0·005 pint/gall.	0·7 mL./L.

Room temperature; 3 volts.; 3–4 seconds; anodes, tank sides, the tank being of welded iron.

(It is observed that this solution is more concentrated than the one described by Wallbank, *loc, cit.*, but that it does not approach the concentration of zinc-plating solutions conventionally employed.)

Swilling in running water

Brass Plating

	oz./gall.	g./L.
Copper acetate	1·6	10·0
Zinc chloride	2·24	14·0
Sodium carbonate	1·6	10·0
Sodium bisulphite	2·54	14·0
Potassium cyanide	6·8	42·5
Ammonium chloride	0·32	2·0

Room temperature; 10 amp./sq. ft.; 2 volt.; 2 seconds; anodes 70–30 brass sheet, or copper and zinc anodes, the copper area being twice that of the zinc. Tank, welded iron.

(Attention is called to the fact that this solution differs from the brass plating bath used by Wallbank, in (*a*) concentration, (*b*) ratio of zinc to copper, (*c*) use of potassium cyanide in place of sodium cyanide, and (*d*) addition of ammonium chloride.) It has been found that, as an alternative to this solution, any of the recognized proprietary brands of brass-plating solution can be used successfully.

Swilling in running water

Neutralizing

10 per cent. tartaric acid; room temperature; 5 seconds in wooden lead-lined tank.

Nickel Plating

	oz./gall.	g./L.
Nickel sulphate	16·0	100·0
Sodium sulphate	2·4	15·0
Boric acid	1·6	10·0
Citric acid	0·4	2·5
Sodium citrate	2·4	15·0

35–40°C.; 10–20 amp./sq. ft.; 2½–3 volt.; 20 minutes; pH 5·6.

Continuous pressure filtration through kieselguhr; agitation by means of filtered air; standard-type tank; anode area 1½ × cathode area.

(The comment is made that this nickel-plating solution (1) has a much lower nickel-ion concentration than the bath described by Wallbank, (2) does not contain any chloride, (3) has a higher nickel-ion concentration than that suggested for the plating of brass, and a lower sulphate content; (4) contains no fluorides, although such an addition is usually made, as a mould-inhibitor, to citrate-containing baths. It is recorded that, over a number of years no mould-growth has occurred with this solution.) Alternatively, any good brand of solution producing a soft nickel deposit is satisfactory for use in this sequence.

Swilling in cold running water

Removal from jigs

In the as-plated state the deposit is relatively non-adherent. The coating should be considered as an 'envelope', which may be easily ruptured or damaged. The work is placed on iron trays, for heat-treatment within the range 400°–500°F. (205°–260°C.). The time and exact temperature of treatment depend on the thickness of the basis material and the shape of the article. The heat-treatment bonds the nickel coating to the aluminium, probably by diffusion of the thin zinc and brass layers into the aluminium, followed by slight diffusion of the nickel into the aluminium. After heat-treatment the articles are polished or coloured, and 'cleaned' with dry lime. They are then chromium plated without preliminary cleaning, and after this operation are dried in a slow oven for five minutes at 350°–400°F. (177°–205°C.), and finished by conventional methods.

The layout of the plant used is diagrammatically illustrated.

Testing of Tin-Nickel Alloy Coating

S. C. BRITTON and D. G. MICHAEL: 'Tin-Nickel Alloy Coatings; Estimation of Thickness and Porosity.' *Bull. Inst. Metal Finishing*, 1953, vol. 3, Autumn, pp. 143–62; *Trans. Inst. Metal Finishing*, 1953, vol. 29.

Investigation of the properties of the 65–35 per cent. tin-nickel alloy coatings developed by the Tin Research Association has shown the need for adequate thickness and low porosity, in order that the full value of the coatings may be realized. It has also been found that the deposits are characterized by a degree of corrosion-resistance which makes difficult measurement of thickness by a jet test or by stripping of the coating, and that conventional porosity tests do not give entirely satisfactory indication of the soundness of this type of deposit.

The present paper records experimental work carried out to establish reliable procedures for estimation of (*a*) thickness, (*b*) porosity.

I. Estimation of Thickness

One method already developed involves solution of the complete coated test sample, in *aqua regia*, and subsequent determination, by chemical analysis, of the quantity of tin present. Although such procedure is undoubtedly accurate when operated by a competent analyst, a simpler and less destructive method was required. The suitability of the following tests was investigated, and results obtainable by the more promising among them were compared:—

(1) Stripping of the deposit by immersion in a suitable reagent which could be restrained from attacking the basic metal.
(2) Anodic stripping in a suitable bath, under conditions which would promote passivity in the basic metal.
(3) Magnetic testing.
(4) Mesle's Chord method.

II. Estimation of Porosity

Methods suggested in British Standard specification 1224 : 1945 for application to nickel + chromium coatings on steel (ferricyanide, hot-water, and salt-spray tests) were investigated, with regard to their applicability in testing tin-nickel alloy coatings. A sulphur-dioxide test is proposed as an alternative method.

The general conclusions reached as a result of the experimental work recorded are summarized below:—

(1) The thickness of tin-nickel coatings on copper or brass may be determined accurately by measurement of weight-loss when the coating is removed either by immersion in concentrated phosphoric acid at 180°C. or by anodic treatment in 10 per cent. hydrochloric acid at 300–400 amp./sq. ft.
(2) The thickness of tin-nickel coatings deposited over copper on steel may be determined by estimation of the tin-nickel removed by anodic treatment in 10 per cent. hydrochloric acid, by means of a magnetic instrument, or by loss of weight. If the copper coating is much below 0·0005 in., pitting of the steel base may occur and the loss-of-weight measurement may thereby be rendered inaccurate.
(3) If suitably calibrated, a magnetic thickness measurer may be used to obtain indications of total thickness of coating, or, in combination with anodic stripping of the tin-nickel layer, to obtain the thickness of the tin-nickel and copper layers when both are present.
(4) Mesle's chord method appears to be suitable only as a rough guide to coating thickness, but if, for a particular method of application, it were calibrated against a more accurate method, it might be used for inspection testing.
(5) The ferricyanide test for porosity is improved in its prediction of performance in natural weathering if the samples are cathodically cleaned before the test is made.

(6) Salt-spray tests predict the number of pores likely to appear in natural weathering only if the test is continued for some weeks, and even then pore behaviour is that seen in marine exposures only.
(7) Exposure of tin-nickel samples over a sulphur dioxide solution, for 24 hours, followed by a brief exposure to ammonia, provides a convenient method of revealing the number of pores and the appearance of the surface likely to develop in inland weathering exposure.

Nickel-Chromium Alloy Coating of Parts of Upsetting Machine

See abstract on p. 198.

NON-FERROUS ALLOYS

B.S. Specifications for Aluminium Bronze and Nickel-Aluminium Bronze

BRIT. STANDARDS INSTN.:
'Aluminium Bronze Rods. Sections and Forgings for General Engineering Purposes.' *B.S.* 2032: 1953.
'Aluminium-Nickel-Iron Bronze Rods and Forgings for General Engineering Purposes.' *B.S.* 2033: 1953.

These Standards are two of a series of specifications for copper and copper-alloy rods, sections and forgings for general purposes. In order to reduce the number of alloys of the aluminium-bronze class, two compositions have been chosen which have characteristics and mechanical properties covering, as far as possible, the requirements for all known applications of such materials. In B.S. 2032 a compromise has been made between the compositions covered by D.T.D. 160 'Aluminium Bronze for Valve Seats' and D.T.D. 174, 'Aluminium Bronze Sand or Die Castings'. In B.S. 2033 the composition approximates to that already familiar as Ministry of Supply material specification D.T.D. 197. The limits of both B.S. specifications are shown below:

B.S. 2032—Aluminium Bronze	%
Aluminium	8·8–10·0
Iron and nickel together	3·0 max.
Manganese	0·5 max.
Total impurities	0·5 max.
Copper	remainder

The following elements are classed as impurities, and are limited as shown—

	%
Lead	not more than 0·05
Tin	„ „ „ 0·10
Zinc	„ „ „ 0·40
Silicon	„ „ „ 0·10
Magnesium	„ „ „ 0·05

Requirements are laid down for minimum tensile strength and elongation, and for rods and sections an (optional) bend test is specified.

B.S. 2033—Aluminium-Nickel-Iron Bronze	%
Aluminium	8·5–11·0
Nickel	4·0–6·0
Iron	4·0–6·0
Manganese	0·5 max.
Total impurities	0·5 max.
Copper	remainder

The following elements are classed as impurities, and are limited as shown—

	%
Lead	not more than 0·05
Tin	„ „ „ 0·10
Zinc	„ „ „ 0·40
Silicon	„ „ „ 0·10
Magnesium	„ „ „ 0·05

Provision is made, in the case of both rods and forgings, for test of tensile properties to specified values for 0·1 per cent. proof stress, tensile strength, and elongation.

Removal of Restrictions on Use of Nickel

See abstract on p. 183.

Corronel B: Properties and Applications

See abstract on p. 199.

Vanadium-Nickel and Other Vanadium Alloys: Summary Data

W. ROSTOKER and A. YAMAMOTO: 'A Survey of Vanadium Binary Systems.' *Amer. Soc. Metals, Preprint 29*, Oct., 1953; 26 pp.

The authors make a survey of existing knowledge on twenty-one binary systems of vanadium. The discussion of each system is divided into two parts: a review of the literature, and a report of experimental work. The summary of the work of other investigators is supported by a *bibliography* of 67 items.

The information relating to the vanadium-nickel system is summarized below:—

Literature review: Studies of the solidification range for a series of alloys containing more than 64 per cent. of nickel showed a minimum at 1335°C. and 79 per cent. nickel. Between 64 and 80 per cent. nickel the structures were two-phase. The existence of sigma phase in this system has been established; limits for its occurrence have been set at 38–48 per cent. nickel.

Authors' Experiments: Alloys containing up to 60 per cent. of nickel were used. The solubility limit of nickel in vanadium appears to be between 7 and 10 per cent. of nickel: the as-cast 10 per cent. alloy showed an interdendritic phase. At least three intermediate phases are found in the vanadium-nickel system: a V_3Ni (27·74 per cent. nickel) phase was found to be isomorphous with V_3Co. This V_3Ni phase, which had not previously been reported, has a β-tungsten cubic structure and a lattice parameter $a = 4·70$ kX. The V_3Ni phase enters into equilibrium with the vanadium solid solution, but the microstructures are complex. A third unknown phase is present in alloys containing 15 and 20 per cent. of nickel. Alloys containing 30–45 per cent. of nickel give diffraction patterns consisting predominantly of sigma phase: the lattice type

of this phase is discussed in relation to data published by earlier investigators. The 60 per cent. nickel alloy showed primary dendrites and interdendritic divorced eutectic. Nickel solid solution was identified as being present in this structure.

The other systems covered in the paper are the binary alloys of vanadium with beryllium, boron, carbon, nitrogen, oxygen, aluminium, silicon, titanium, chromium, manganese, iron, cobalt, copper, zirconium, niobium, molybdenum, silver, tin, tantalum, and tungsten.

Lead-Free Paints for Marking High-Nickel Alloys

'Marking High-Nickel Alloys.' *Machinery* (*Lond.*), 1953, vol. 83, Sept. 18, p. 576.

Alloys containing high percentages of nickel are subject to embrittlement when heated above 300°C. in the presence of sulphur, or of low-melting-point metals such as lead, cadmium, or zinc. This note gives details of paints and other marking media which have proved suitable for use on alloys of the Nimonic series and other high-nickel alloys.

NICKEL-IRON ALLOYS

Propagation of Martensite in Iron-Nickel Alloy

R. F. BUNSHAH and R. F. MEHL: 'Rate of Propagation of Martensite.' *Jnl. of Metals*, 1953, vol. 5, Sept., Sect. 2; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1251–8: T.P. 3604 E.

This paper describes fast amplifier technique developed by the authors for measurement of the rate of propagation of martensite. The material on which the determinations were made was an alloy containing nickel 29·5 per cent., balance iron. The time of formation of a plate of martensite 0·01 in. long in this alloy was found to be $3 \cdot 10^{-7}$ sec.: it is believed that this is the most accurate value yet reported for propagation of martensite. Rate of propagation is approximately 3,300 ft. per sec., or 100,000 cm. per sec. and, in the alloy studied, is independent of temperature within the range −20° to −195°C. Thus, the 'activation energy' for the propagation of martensite is virtually zero.

It is concluded from the findings reported above that the concept of martensite formation by a process of atom-by-atom growth is incorrect, but the results are in good accord with the strain-wave propagation theory which has been proposed for the martensite transformation. The characteristics of the transformation (time of transformation of martensite units, and general nature of the pulse cycle resulting from the martensite transformation) are independent of whether the change occurs athermally or isothermally.

It is considered by the authors that the experimental technique described is ideally suited for the study of rapidly occurring phenomena in metals and alloys, e.g., slip, twinning, cleavage, etc., for which they are already employing it.

Removal of Restrictions on Use of Nickel

See abstract on p. 183.

CAST IRON

Removal of Restrictions on Use of Nickel

See abstract on p. 183.

Heat-Treatment of S.G. Iron

M. BALLAY, R. CHAVY and J. GRILLIAT: 'Heat-Treatments for Spheroidal-Graphite Cast Irons.' *International Foundry Congress*, 1953, Sept., Paper MO–11; 23 pp.

Whilst S.G. iron is frequently used in the annealed condition, annealing is not the only heat-treatment which can, with advantage, be applied to it. Many of the treatments used for steels are also applicable to cast iron, and this paper is devoted to a review of the conditions which may be used in heat-treating S.G. irons to obtain given combinations of properties.

The subject is dealt with, in considerable detail, under the headings of graphitization of cementite; ferritization of pearlite; normalizing; martensitic quenching and tempering; influence of speed of cooling and of tempering conditions; hardening by local quenching; stress-relief annealing. The paper contains much information, based on carefully controlled heat-treatments.

Fatigue Properties of S.G. Iron

K. B. PALMER and G. N. J. GILBERT: 'The Fatigue Properties of Nodular Cast Iron.' *Brit. Cast Iron Research Assocn. Jnl. of Research and Development*, 1953, vol. 5, Aug., pp. 2–14.

Tests have been made, in the laboratories of the British Cast Iron Research Association, to determine the fatigue strength of a range of cast irons treated with magnesium+cerium. The tests were made in a Wöhler machine, on both as-cast and annealed material, using un-notched, as well as notched, specimens. The compositions were planned to study, *inter alia*, the influence of silicon content, up to 4 per cent. The conclusions drawn from the tests are as follows:—

Silicon increased the un-notched fatigue limit of ferritic nodular irons, and either decreased or had little effect on, the notched fatigue limit, causing the dynamic stress-concentration factor

$$\frac{\text{un-notched fatigue limit}}{\text{notched fatigue limit}}$$

to increase with rise in silicon content.

Silicon had little effect on the un-notched fatigue limit of pearlitic nodular irons, but decreased the notched fatigue limit, causing the dynamic stress-concentration factor to increase with silicon content, as in the ferritic irons.

The tensile strength of the as-cast pearlitic irons decreased with rise in silicon content, though not always consistently.

Endurance ratios of the pearlitic and ferritic irons fell with increase in tensile strength, but the relationship was different for the two types of material. The endurance ratios of the heat-treated irons also fell with rising silicon content. While these results indicate

that increase in silicon content, within the range studied, improves the static tensile properties and the un-notched fatigue properties of ferritic nodular irons, the warning must be given that increasing silicon has a harmful effect on impact properties (*ibid.*, 1953, vol. 4, pp. 458–78).

Specifications and Tests for S.G. Iron

M. BALLAY and J. GRILLIAT: 'Specifications and Tests for Spheroidal-Graphite Cast Irons.'
International Foundry Congress, Sept., 1953, Paper CI-21; 19 pp.

The authors review conditions for testing and specification of iron castings, and describe test-bar castings for determining the properties of S.G. iron. The only general standard specification yet issued for S.G. iron is that sponsored by the American Society for Testing Materials (A.S.T.M. A 339-51T). Certain other organizations have, however, issued their own specifications, e.g., the Italian State Railways, and in France a schedule has been prepared by l'Association pour le Développement et l'Utilisation des Fontes à Graphite Sphéroïdal. This latter document covers three grades of S.G. iron: (1) pearlitic, (2) ferritic-pearlitic, and (3) ferritic. Type 1 is usually not heat-treated; type 2 may, or may not be, heat-treated; type 3 is always annealed.

The authors of this paper show that the hardness required in a casting, in order to obtain optimum service, is frequently the determining factor, and that hardness can be related (as shown by curves in the paper) to the other properties: tensile strength, yield strength, and elongation. The characteristics of the three grades of iron are discussed, and critical consideration is given to the form of test piece most suitable for determination of the properties of the respective types. Test pieces are illustrated, and conditions for tensile, hardness, and bend testing are described.

In the appendix, properties of S.G. iron as determined on various forms of test piece are given.

CONSTRUCTIONAL STEELS

Removal of Restrictions on Use of Nickel

See abstract on p. 183.

Influence of Chemical Composition of Steels on Susceptibility to Temper-Brittleness

R. HULTGREN and J. C. CHANG: 'Effect of Chemical Composition on Susceptibility of Steels to Temper-Brittleness.' *Amer. Soc. Metals, Preprint 26*, Oct., 1953; 14 pp.

In the investigation reported, compositions were varied over a wide range, and purity of experimental materials used was ensured by melting together the pure elements under helium.

Specimens were heat-treated by quenching from the austenite region, and tempering for one hour at 600°C. (1110°F.). After tempering, one member of a closely similar pair of specimens was removed from the furnace and quenched, whilst the other was allowed to cool slowly. Both were then subjected to impact test at identical temperatures, and if the slowly cooled sample showed a lower impact strength it was deemed to be susceptible to temper-embrittlement. In view of the important effect of temperature of test on revelation of susceptibility to embrittlement, impact determinations were made over a range of temperatures. The data presented are based on the use of standard V-notch Charpy bars.

From preliminary tests on a number of commercial steels, supplemented by determinations on the synthetic high-purity materials, the authors discuss the mechanism of temper-brittleness, and the influence of individual elements on susceptibility. The principal findings are summarized below.

Mechanism of Temper-Brittleness: The simplest hypothesis, and the one most generally held to be valid, is that embrittlement is caused by precipitation of a small amount of an as yet unidentified phase. The authors conclude that 'if embrittlement is due to such a precipitate, and if only one precipitating phase is the cause, the evidence in this paper points clearly to iron carbide as the precipitating phase.' Apart from impurities, iron and carbon are the only elements which occur in all susceptible materials.

Effects of Carbon: Binary iron-carbon alloys were slightly, but unmistakably, susceptible when the carbon content was 0·11 per cent. or even less. In many of the materials tested, particularly the S.A.E. 3300 nickel-chromium steel series, the greatest embrittlement was observed at carbon contents of 0·15–0·20 per cent. Carbon contents above 0·2 per cent. decidedly decrease the maximum impact energy, and raise the transition temperatures in the unembrittled state.

Effects of Nickel: More than 3·1 per cent. of nickel is necessary to make iron +0·2 per cent. carbon alloys susceptible, and in this case the effect is not large. Small amounts of chromium reinforced the effect only slightly, but manganese had a stronger influence. In the presence of both chromium and manganese, in the percentages found in S.A.E. 3312 (1·5 and 0·5 per cent., respectively), pronounced temper-brittleness was found only when the nickel content exceeded 2 per cent. Severe embrittlement occurred, however, with nickel contents over 3 per cent. in this type of steel. The tests confirmed the beneficial influence of nickel in lowering the transition temperature of unembrittled steels. In amounts above 3 per cent. nickel appears to lower the maximum impact strength, an effect which may be attributable to increase in amount of retained austenite.

Effect of Manganese: In amounts of 2 per cent. or above, this element produces a higher degree of susceptibility to embrittlement, and iron-carbon-chromium-nickel alloys are made strongly susceptible by the addition of only 0·5 per cent. of manganese. In general, manganese appears to be more potent than chromium or nickel in causing liability to embrittlement. Small additions of manganese impart sufficient hardenability to iron-carbon alloys to lower their

transition temperatures appreciably, but further additions raise the transition temperatures to values extending far above room temperature.

Effect of Chromium: In the absence of other alloying elements chromium gives rise to little or no susceptibility to embrittlement, but it may cause, or markedly enhance, embrittlement of iron-carbon alloys containing manganese, nickel, or phosphorus. In steels in which chromium confers necessary hardenability it lowers transition temperatures: in other cases its effect is not pronounced in this respect.

Effect of Phosphorus: A few hundredths of a per cent. of phosphorus will render non-susceptible iron-carbon-chromium alloys pronouncedly susceptible to embrittlement.

Effect of Inclusions on Fatigue-Resistance of Nickel-Chromium-Molybdenum Steels

J. T. RANSOM: 'The Effect of Inclusions on the Fatigue Strength of S.A.E. 4340 Steels.'
Amer. Soc. Metals, Preprint 12, Oct., 1953; 10 pp.

In a paper to the American Society for Testing Materials, in 1952, RANSOM and MEHL drew attention to the fact that the service life of many forged machine parts depends upon the fatigue limit measured in a direction transverse to the fibre of the forging, and that the limit in this direction may be considerably lower than that measured in the direction parallel to the fibre. It has been suggested that the elongation of non-metallic inclusions during the forging operation is responsible for the lower fatigue properties in the transverse direction.

The first part of the present paper offers direct evidence that non-metallic inclusions nucleate the fatigue cracks in transverse bend specimens and in most torsion specimens, of any orientation. In the second part of the paper it is shown that virtual elimination of non-metallic inclusions results in a large increase in transverse fatigue limit, so that it approaches the value of the fatigue limit in the longitudinal direction.

The investigation was made on two commercial steels, and on a vacuum-melted steel, all of the S.A.E. 4340 nickel-chromium-molybdenum type. Analyses of the three steels are given in the table.

	Commercial Steels		Vacuum-Melted Steel
	A	B	
Carbon ..	0·36	0·417	0·39
Silicon ..	0·30	0·259	0·37
Manganese ..	0·62	0·74	0·69
Sulphur ..	0·014	0·017	nil
Phosphorus ..	0·012	0·022	nil
Nickel	1·82	1·77	1·78
Chromium ..	0·96	0·88	0·97
Molybdenum ..	0·37	0·27	0·31
Vanadium ..	0·11	—	0·13
Nitrogen ..	$5{\cdot}6\times10^{-3}$	—	$2{\cdot}5\times10^{-4}$
Oxygen ..	$5{\cdot}6\times10^{-3}$	—	$1{\cdot}8\times10^{-3}$

Technique and specimens used in bend- and torsion-fatigue tests on heat-treated bars of all three steels are detailed in the report. In steel A the transverse fatigue limit was only 52 per cent. of that obtained in the longitudinal direction, and in steel B (aircraft quality) the transverse value was 68 per cent. of that of the longitudinal. Examination of the failed specimens provided reasonable explanation for the differences. All transverse bend specimens in steel A failed from a crack which started at an inclusion, and the torsional fatigue specimens confirmed the effect of inclusions in lowering fatigue strength.

In the vacuum-melted high-purity steel the bending-fatigue limit obtained with transverse specimens was 50 per cent. higher than that shown by the commercial steel forgings, and approached the value obtained with longitudinal specimens of the same steel. It is therefore concluded that non-metallic inclusions are a major source of fatigue weakness in many forged parts, and that steelmaking research should be directed towards development of methods which will eliminate inclusions, or minimize their effects.

Notch-Tensile Properties of Nickel-Alloy Steels and High-Temperature Cobalt-Nickel-Chromium-base Alloys

H. SCHWARZBART and W. F. BROWN: 'Notch-Bar Tensile Properties of Various Materials and their Relation to the Un-Notch Flow Curve and Notch Sharpness.' *Amer. Soc. Metals, Preprint 37*, Oct., 1953; 24 pp.

The primary objective of the investigation described was the determination of the effects of strain-hardening characteristics and notch sharpness on notch-tensile properties. Circumferentially notched tensile bars of the following materials were tested: annealed brass, annealed and hard-drawn copper, titanium, aluminium alloy, and S. 816 (cobalt 43, nickel 20·4, chromium 19·8, molybdenum 4·3, niobium 3·51, iron 2·8, manganese 1·53, carbon 0·38, silicon 0·26, per cent.). Data available from other investigations, on carbon steel and low-alloy nickel-chromium steel, were correlated with the authors' results.

It was found that as the sharpness of notch increases, the true stress-strain curve is raised and ductility decreases. These effects manifest themselves in two ways: (1) the yield strength increases rapidly at low sharpnesses, decreasing in rate of rise at higher sharpnesses; (2) the notch strength and fracture stress usually increase at low sharpnesses of notch, ultimately reach a maximum, and subsequently decrease at higher sharpnesses.

The higher the un-notched necking strain, or the higher the rate of the strain-hardening, (*a*) the slower is the rate at which triaxiality increases with sharpness of notch, (*b*) the less is the amount of triaxiality developed, and (*c*) the higher is the sharpness at which triaxiality is developed. A correlation was found between the rate of strain-hardening and the extent to which ductility is reduced by the presence of a sharp notch.

Low-Temperature Properties of Steels

K. JANIS: 'Bibliography on Low-Temperature Characteristics of Steels, 1904–June, 1953.'
Reprint of paper presented to American Special Libraries Association, Oct., 1953; 45 pp.

The *bibliography* comprises a list of the titles of 468 items, arranged in chronological order. An author index is provided.

Strength and Ductility of Metallic Materials at Elevated Temperatures: A.S.T.M. Symposium

See abstract below.

Cast Nickel-Chromium Steel Bathysphere

'Notable Steel Castings.' *Foundry Trade Jnl.*, 1953, vol. 95, Oct. 1, pp. 429–30.

Illustrated notes on three out-of-the-ordinary steel castings, in which size, complexity of form, and novelty of use are outstanding features. One of the items to which reference is made is the bathysphere, made, in 1947, for deep-sea experiments by Professor Piccard. The vessel weighed about 13 tons, and was cast in two halves from a self-hardening type of nickel-chromium-molybdenum steel manufactured, under the name of 'Infatigable', by Usines Emile Henricot, under licence from Société Delachaux. The steel was required to give high tensile strength combined with adequate ductility, and perfect homogeneity in the casting was an essential feature. The depth attained in Professor Piccard's experiment (2100 metres; 6,400 feet) demonstrated the soundness and water-tightness of the casting.

HEAT- AND CORROSION-RESISTING MATERIALS

Removal of Restrictions on Use of Nickel

See abstract on p. 183.

Strength and Ductility of Metallic Materials at Elevated Temperatures: A.S.T.M. Symposium

AMER. SOC. TESTING MATERIALS: 'Symposium on Strength and Ductility of Metals at Elevated Temperatures, with Particular Reference to Effects of Notches and Metallurgical Changes.'
A.S.T.M. Special Technical Publn. 128, 1953: 249 pp.

This publication contains papers and discussions presented during sessions held as part of the 55th Annual Meeting of the Society in June, 1952. The symposium was sponsored by the Joint A.S.T.M.–A.S.M.E. Committee on Effect of Temperature on the Properties of Metals. The scope of the individual contributions is shown below.

J. D. LUBAHN and G. V. SMITH: 'Introductory Summary,' pp. 1–5.

Review of the highlights from the other papers which form part of the symposium.

G. SACHS and W. F. BROWN: 'A Survey of Embrittlement and Notch Sensitivity of Heat-Resisting Steels,' pp. 6–20; disc., pp. 21–4.

The phenomenon of embrittlement of steels after heating for prolonged periods has been recognized for many years. Various investigators have differed with regard to the effect of stress in accelerating this embrittlement. A severely weakening effect caused by notches in creep loading, reported recently from some sources, appears to be a closely related phenomenon. The purpose of the present paper is to assemble and evaluate some of the widely scattered information.

In view of the varying methods by which the subject has been studied, results published in different sources are not closely comparable. In this survey, therefore, the authors have summarized separately the results of individual investigations, and, from the data so assembled, have endeavoured to determine the general effects of the important variables involved, to show the inter-relationship of such factors, and to suggest the mechanism by which embrittlement takes place. The subject is considered on the basis of data in the literature relating to embrittlement of steel bolts in service; embrittlement by heating with and without applied loads; embrittlement after creep loading at various stresses; the influence of notches in stress-rupture tests; the general effects of time and temperature. The materials on which experimental data are recorded in the respective sections range from various types of nickel-chromium-molybdenum and other constructional alloy steels to high-alloy steels of the stainless types. From the information thus collated, the authors draw the following tentative conclusions:–

'All the steels investigated were found to be subject to embrittlement or creep damage when heated under applied stress at 932°F. (500°C.). The magnitude of the effect varies widely according to the material.

'Rate and magnitude of creep damage depend on the creep stress. Rate increases with rise in stress: magnitude increases with decrease in stress, to a maximum value, and then for very long times (low stresses) may decrease with fall in stress.

'If creep damage exceeds a certain critical value, which depends on the stress, it cannot be eliminated by a re-heat treatment.

'The creep process results in a permanent damage to the material, which is thought to be associated with flaws or cracks in the structure. For steels which develop a high creep damage this permanent deterioration develops at smaller values of creep damage as the applied stress is lowered. For steels which do not embrittle severely the permanent damage occurs only shortly before rupture.

'Both creep damage and notch rupture sensitivity appear to be associated with precipitation.

'No general conclusion can be reached as to the composition and heat-treatments optimum for securing freedom from embrittlement, but it can be definitely stated that both temperature and time must be considered in selecting materials for service applications, and that freedom from susceptibility to embrittlement at one time and temperature does not ensure immunity at other times and temperatures.'

W. F. BROWN, M. H. JONES and D. P. NEWMAN: 'Influence of Sharp Notches on the Stress-Rupture Characteristics of Several Heat-Resisting Alloys.' pp. 25–45; disc.. pp. 46–8.

The paper reports some results of investigations under prosecution by the National Advisory Committee for Aeronautics, on the notch-sensitivity, at various temperatures, of some materials which are of interest to both steam- and gas-turbine engineers. The data now published relate to tests with only one form of notch, viz., a sharp, 50 per cent., 60°V notch. The materials used were representative low-chromium steel; nickel-chromium-molybdenum steel of S.A.E. 4340 type; low-alloy chromium-nickel-molybdenum-vanadium-tungsten steel; 13 per cent. chromium steel containing 2 per cent. of nickel and 13 per cent. chromium steel having small additions of molybdenum, vanadium and tungsten; a low-carbon titanium-stabilized 15·5–12·5 chromium-nickel steel containing molybdenum, and Inconel 'X' (nickel 72, chromium 15, iron 7 per cent.). Both un-notched and sharply notched bars were tested at various temperatures, and ductility was determined for both notched and un-notched specimens.

All the materials mentioned were subject to weakening by the presence of a notch, but the time and temperature ranges in which this weakening effect occurred, also the magnitude of the effect, varied widely with the composition of the material. The general trend of the results confirms the conception that a precipitation reaction is responsible for notch-sensitivity.

F. C. HULL, E. F. HANN and H. SCOTT: 'Effect of a Notch and of Hardness on the Rupture Strength of 'Discaloy',' pp. 49–58; disc., p. 58.

This is a study of a material selected as representative of precipitation-hardening austenitic materials currently used for high-temperature service in gas turbines and other assemblies. The compositions of various heats given in the paper fall within the following range:—nickel 24·4–27·6, chromium 12·5–14·1, molybdenum 2·77–3·18, titanium 1·40–2·34, aluminium 0·13–0·38, manganese 0·50–0·90, silicon 0·53–1·08, per cent., balance iron. The effects of hardness, as varied by the content of the hardener (titanium), are related in this paper to the behaviour of the material in the presence of a notch. Creep-rupture and notched-bar rupture tests were made at 1000° and 1200°F. (538° and 648°C.). The rupture strength of the plain bar reached a maximum at a hardener content which produced 2 per cent. rupture strain: the notched-bar strength exceeded the strength of the plain bar in material in which the creep specimen had more than 5 per cent. rupture strain. Very critical control of titanium content is necessary to obtain the optimum combination of plain- and notched-bar rupture strength.

D. E. FURMAN and A. M. TALBOT: 'Notched Rupture Tests of Inconel 'X' and Nimonic 80A,' pp. 59–66.

In the experiments reported, some of the tests were made with a deep notch (on the presumption that the results of such tests could correlate with the service behaviour of threaded parts or with that of the fir-tree base of turbine blades), whilst others were with a sharp, but quite shallow, notch (with the aim of obtaining some assessment of damage to be expected from accidental nicks and scratches). The tests were made on the materials in the condition as treated to produce optimum high-temperature properties:—

Inconel 'X': solution treated at 2100°F. (1150°C.) for 4 hours, air-cooled, and aged 24 hours at 1550°F. (842°C.), followed by 20 hours at 1300°F. (704°C.).

Nimonic 80A: solution treated at 1975°F. (1077°C.) for 8 hours, air-cooled, and aged at 1300°F. (704°C.) for 16 hours.

Temperatures of test were 1100°, 1350° and 1500°F. (593°, 734° and 815°C.) for Inconel 'X', and 1350° and 1550°F. (734° and 815°C.) for Nimonic 80A.

In tests with rupture specimens having a circumferential notch 0·042 in. deep and a root radius of 0·005 in., neither material is notch-sensitive except after prolonged periods at temperatures of minimum ductility. Limited tests at 1100°F. (593°C.) indicate little possibility of notch-sensitivity at that temperature. At 1350°F. (734°C.) the absence of notch-sensitivity extends to rupture times of 400 hours for Inconel 'X' and to 1000 hours for Nimonic 80A. At 1500°F. (815°C.) neither material shows any tendency to notch-sensitivity.

There is no conclusive evidence that notch-sensitivity in these alloys is associated with any particular ductility value, but there is reason to believe that some correlation exists between the presence of numerous cracks in a fractured rupture specimen and the lack of notch-sensitivity.

Both alloys were found to be insensitive at 1350°F. (734°C.) to the shallow notch 0·002 in. deep, having a 0·002 in. radius, which was used to simulate accidental surface imperfections.

E. A. DAVIS and M. J. MANJOINE: 'Effect of Notch Geometry on Rupture Strength at Elevated Temperatures,' pp. 67–87: disc., pp. 88–92.

The authors report results of three series of creep-rupture tests on notched bars having varying geometry of notch. The materials investigated were typical high-temperature alloys selected (as to composition) to be representative of (*a*) materials having good ductility, (*b*) materials showing specially high strength and hardness, or (*c*) design materials on which data were specially required:—

Refractaloy 26: nickel-chromium-cobalt-iron-base precipitation-hardening alloy which contains titanium and molybdenum, and can be treated to produce various degrees of hardness or ductility. It was tested in three conditions.

Steel containing chromium 12, tungsten 3, per cent., selected on account of its ductility, and of its stability at test temperature.

K. 42-B: a precipitation-hardening austenitic alloy, differing from Refractaloy 26 in that it does not contain molybdenum.

19-9 DL: one of the more ductile of the stainless-steel type of 'Super Alloy'.

Test temperatures used were 1200° and 1000°F. (648° and 538°C.).

In addition to determination of the influence of shape of notch, the tests were designed to cover a study of the influence, on notch-sensitivity, of the following factors: level of stress, grain size, hardness, ductility, and heat-treatment.

It was found that the effect of increasing the sharpness of the notch varies according to the ductility and microstructure of the alloy: metals characterized by a high un-notched ductility exhibit a 'strengthening' effect in specimens having notches as sharp as can be accurately ground. The strengthening effect diminishes, and notch-sensitivity increases, with decrease in ductility.

Levels of stress did not appreciably affect the relative notch-sensitivities of the materials studied: there was only slight indication that notch-sensitivity increased with decreasing stress. In a notched specimen under constant load the time required to initiate a crack which will propagate is much longer than the time taken for it to travel across the minimum section.

W. SIEGFRIED: 'Investigations into the Influence of Notches on Creep Strength at High Temperatures,' pp. 93–130.

This paper gives results of tests made in the laboratories of Sulzer Brothers, Ltd., in connexion with design of the Company's gas-turbine plants. The greater part of the work was at elevated temperatures, on austenitic steels, but in order to throw further light on certain basic aspects of the question, some tests were made also on tin-cadmium alloys, at room temperature. Full analyses are given of all the materials examined, which include many variants of the '18-8' type of chromium-nickel steel, and austenitic steels of somewhat higher chromium and nickel contents; a nickel-chromium-base alloy (75·3/19·4 per cent.), and binary alloys of tin containing 6 and 1·4 per cent. of cadmium. On the basis of the mechanical tests made, and examination of structure, the ferrous materials and the nickel-chromium-base alloy are arranged in order of their increasing susceptibility to brittleness in high-temperature service. It is shown that embrittlement which may occur in some austenitic steels at elevated temperatures depends on duration and conditions of exposure. Such deterioration is due to a large extent to precipitation processes taking place in the steels at the temperatures of operation. Strength of the grain boundaries also plays an important part in determining susceptibility or resistance to embrittlement. The investigations on the tin-cadmium alloys indicate that precipitation may be influenced by creep processes. The tests revealed some relation between elongation values at rupture (measured on smooth specimens in creep tests) and embrittlement phenomena.

D. N. FREY: 'Theory of Time-Dependent Rupture and Interpretation of Some Stress - Rupture Data,' pp. 131–7; disc., pp. 138–41.

It is shown that time-dependent rupture is reasonably to be considered as two types of process. At short times and high stresses rupture is flow-induced, i.e., dislocations which are started, and then stopped by various types of barrier, condense and form a microcrack of critical size, which can grow by the Griffith theory. At long times and low stresses, where creep is negligible, rupture is of a truly brittle nature. Here microcracks initially present in the lattice have time sufficient for them to grow, by random thermal oscillations, to critical size. It is pointed out that (*a*) the increased time to rupture resulting from precipitation with rather large spacings (more than 10^{-5} cm.) in austenitic alloys, and (*b*) the opposite effects of circumferential notches on time to rupture at short and at long times are both explicable on the basis of the above theory.

P. R. TOOLIN: 'The Effect of Grain Size upon the Fatigue Properties, at 80°, 1200° and 1600°F., of 'Precision Cast' Alloy X-40,' pp. 142–59; disc., pp. 160–2.

The work reported in this paper is part of a general investigation of the fatigue properties of high-temperature precision-cast (investment-cast) materials. The alloy on which the tests were made is one which has been used for various high-temperature components, including rotating gas-turbine blades. The chemical composition of the heat from which the test specimens were prepared is given as: carbon 0·50, nickel 10·8, chromium 25·1, cobalt 53·6, tungsten 7·42, molybdenum 0·22, iron 0·82, manganese 0·48, phosphorus 0·005, silicon 0·82, per cent. The alloy is variously known as X-40, or Stellite No. 31: it complies with S.A.E. (A.M.S.) specification 5382. The conclusions given below are based upon a specific set of tests, in which the conditions were as follows:—

The precision-cast fatigue specimens had a circular cross section of 0·33-in. min. diameter. In casting these specimens the mould temperature was held constant, and the pouring temperature was varied, to give variation in grain size of the alloy. The un-notched specimens were ground and polished, whilst the 0·015-in. radius semi-circular notches were only ground, or, in certain defined cases, machined. Except for overnight stabilization at the test temperatures (1200° and 1600°F.: 648° and 870°C.), the fatigue-test specimens were not heat-treated in any way. Fatigue-resistance was determined by completely-reversed-loading repeated-bending tests, made at a frequency of 7200 c.p.m.

Within these limiting conditions, the following observations are made:—

At temperatures up to 1600°F. (870°C.) precision-cast X-40 has a higher un-notched average fatigue strength when it is poured at low temperatures, with resulting finer grain size, than when poured at high temperatures, which produce larger grain size. Extrapolation of the data obtained at 7200 c.p.m., indicates that at temperatures above 1650°F. (900°C.) material of coarse-grained structure might show superior resistance to fatigue.

As-cast X-40 has a higher un-notched fatigue strength at 1200°F. (648°C.) than at room temperature. At room temperature the notched fatigue strength of the fine-grained specimens was greater than that of the coarse-grained material, but at both

1200°F. (648°C.) and 1600°F. (870°C.) average notched fatigue strength does not appear to be dependent on grain size. Thus, the effect of variation in grain size is much greater for un-notched specimens than for notched ones, i.e., the gain which might be expected in fine-grained material is apparently offset by its greater notch-sensitivity.

In the as-cast condition, this alloy shows its maximum notch-sensitivity in the region of 1200°F. (648°C.), but even at this temperature it would not be considered severely notch-sensitive. At 1600°F. (870°C.) the sensitivity factor is approaching zero.

Fatigue tests on specimens having machined notches indicated that the bending-fatigue strength of X-40, at both room temperature and at 1200°F. (648°C.) can be appreciably improved by cold-working the surface.

H. A. LEQUEAR and J. D. LUBAHN: 'Recovery and Creep in an Alloy Steel,' pp. 163–79; disc., pp. 180–3.

By interrupting a creep test and observing that the creep rate is higher after such interruption than before, (by amounts increasing with the prolongation of the interruption) it is possible to establish that recovery (reduction of the amount of strain-hardening) has taken place. In this paper experiments on a chromium-molybdenum-vanadium steel are reported. These show that in quenched-and-tempered steel of this type recovery occurs in interrupted tests at 1000°F. (538°C.), but not at 800°F. (425°C.).

J. GLEN: 'An Experimental Study of the Strength and Ductility of Steel at Elevated Temperatures,' pp. 184–221; disc., pp. 222–4.

The object of the investigation reported was to explain the effect of various tempering treatments on the creep-resistance of carbon and low-alloy steels, and to elucidate the probable behaviour of such steels during long-term service at high temperatures. Preliminary tests indicated that the problem was related to precipitation hardening, since creep and tension tests carried out over a range of temperatures showed that an increase or decrease in resistance to deformation could be brought about by different tempering treatments. True-stress-strain tension tests were then made on low-carbon steels containing varying amounts of manganese and molybdenum. Steels killed with aluminium were also tested. In the absence of manganese and molybdenum a maximum in the stress for given strain was found at about 200°C. When manganese was added a second maximum appeared, at about 300°C., and when molybdenum was present it occurred at about 500°C. These maxima are attributed to precipitation of carbides during straining, the type of carbide formed depending on the testing temperature and the alloying elements present. To each maximum in stress there is a corresponding minimum in ductility, suggesting that the strain preceding rupture is also related to the precipitation of carbides, in this case at the grain boundaries. The results of the tests, which also gave information on the influence of tempering, make it possible to explain many of the effects of alloying elements on the creep-resistance and ductility of steels under various conditions of testing.

G. V. SMITH and E. J. DULIS: 'Effect of Sigma on Strength and Ductility of 25 Cr, 20 Ni Steel,' pp. 225–35; disc., p. 236.

Study of the influence of sigma phase in a steel of the following composition: carbon 0·07, silicon 0·53, manganese 1·81, phosphorus 0·024, sulphur 0·013, copper 0·10, chromium 27·24, nickel 22·20, vanadium 0·01, per cent.

Samples of this steel, initially cold-worked about 35 per cent., were heated at 1700°, 2000° or 2300°F. (926°, 1093° or 1260°C.), for one hour and water-quenched, and were subsequently exposed for 7,500 hours at 1300°F. (704°C.), to promote precipitation of sigma phase. Material so treated was compared, in tensile tests, with steel which had not been subjected to sigmatizing treatment.

In all specimens, room-temperature tests showed that sigma caused increased yield and tensile strength, with lowering of elongation and reduction of area. The precipitation of sigma also resulted in severe loss of notch-impact strength within the temperature range −315° to +500°F. (−193° to +260°C.).

Creep-rupture tests at 1300°F. (704°C.), the temperature used for the sigma-precipitation treatment, showed in almost all cases the presence of sigma to be slightly deleterious to mechanical strength, as gauged by either the minimum creep rate or the stress for rupture in a specific time.

A. B. WILDER and E. F. KETTERER: 'The Structure and Properties of Stainless Steels after Exposure at Elevated Temperatures,' pp. 237–46; disc., pp. 247–9.

A selection of well-known steels generally used in the manufacture of tubular products has been exposed (in the laboratories of the National Tube Division, United States Steel Corporation) to temperatures of 900°, 1050° and 1200°F. (482°, 565° and 648°C.), without stress, for periods up to 34,000 hours. The full programme provides for extension of the test period to 100,000 hours.

In this investigation a study is being made of the microstructure of welds and of parent materials, and of tensile and creep-rupture properties. The types of material represented are as follows:—

Straight 12 per cent. chromium steel; 12 per cent. chromium containing special additions of aluminium, molybdenum, or selenium.

Straight 17 per cent. chromium steel.

Straight 27 per cent. chromium steel.

Straight 18–8 chromium-nickel steel and 18–8 of the titanium-, niobium-, molybdenum-, and selenium-bearing types.

Stainless 'W', precipitation-hardening 18–8 chromium-nickel type containing titanium and aluminium.

Chromium-nickel steels, 25–12 and 25–20 types.

Results of the tests are summarized below:—

Tensile properties at ambient temperature were not appreciably changed after 10,000 hours of exposure at any one of the three temperatures, with the exception of the 17 per cent. chromium steel exposed at

900°F. (482°C.), the 18-8-Se exposed at 1050°F. (565°C.), and the 18-8-Mo exposed at 1200°F. (648°C.).

Exposure for 10,000 hours at 900°, 1050° and 1200°F. (482°, 565° and 648°C.) caused change in the rupture properties of 17 per cent. chromium steel at 900°F. (482°C.), 18-8 Ti steel at 900° and 1050°F. (482° and 565°C.), 18-8-Mo at 1050°F. (565°C.), and 18-8-Nb at 1050° and 1200°F. (565° and 648°C.). The creep-rupture properties of the other steels were not appreciably changed by the exposures.

Ductility of the rupture specimens was not, with few exceptions, appreciably altered after 10,000 hours exposure at any of the three temperatures. By comparison with the properties at ambient temperature, ductility in rupture tests of the ferritic steels increased, whereas in the austenitic steels the reverse was the case.

After 34,000 hours of exposure at 1200°F. (648°C.) sigma phase was identified in all the ferritic steels, with the exception of the 12 per cent. chromium steel containing aluminium and the selenium-containing chromium steel. At 1050°F. (565°C.) sigma was observed in the 12 per cent. chromium steel containing ½ per cent. of molybdenum, the 17 per cent. chromium and the 27 per cent. chromium steels.

Sigma was identified also in the stabilized austenitic steels which had been exposed for 34,000 hours at 1050°F. and 1200°F. (565° and 648°C.). The unstabilized steels, which did not show sigma after 10,000 hours of exposure at 1200°F. (648°C.), contained this phase after 34,000 hours. It was not observed in the 25-12 steel, but was found in the 25-20 type after 5,000 hours at 1200°F. (648°C.).

Magnetic-permeability measurements showed the presence of a ferromagnetic constituent in the 18-8-Ti steel after 34,000 hours of exposure at 1200°F. (648°C.). A constituent believed to be ferritic was found in the stabilized steels exposed at 1050° and 1200°F. (565° and 648°C.), and in Stainless 'W' after exposure at all three temperatures.

Influence of Notches on Stress-Rupture Behaviour of High-Temperature Alloys

W. F. BROWN, M. H. JONES and D. P. NEWMAN: 'Influence of Sharp Notches on the Stress-Rupture Characteristics of Heat-Resisting Alloys: Part II'.
Amer. Soc. Testing Materials, Preprint 67, June, 1953; 16 pp.

In an earlier paper (see abstract on p. 191 of this issue of *The Nickel Bulletin*) the authors described tests on several materials of interest to gas-turbine designers. The present paper reports an extension of the work to cover a vanadium-containing modification of steel 17-22 A (low-chromium-molybdenum), a 5 per cent. chromium steel containing about ½ per cent. of molybdenum, and the high-temperature alloy Nimonic 80A (nickel-chromium base, precipitation-hardening type, containing titanium and aluminium). Additional data on the materials tested earlier are also reported. The temperatures of test used in these experiments were, in general, in the range in which the respective materials would be used in service. Data at such temperatures are reported for rupture times varying from 0·1 to 1,000 hours. The results are considered in conjunction with those obtained in the earlier series of tests.

The general time-temperature dependence of the notch effect in stress-rupture tests was confirmed. Analysis of the ductility data shows that the reduction in area of a smooth bar at fracture yields no definite information regarding notch-rupture sensitivity of a given material.

With regard to the properties of the various austenitic (nickel-containing) materials examined, the following comments are made: see table below for compositions of alloys discussed.

	Inconel 'X'	Nimonic 80A	Haynes 88	G.18B
Carbon ..	0·08	0·1 max.	0·07	0·4
Silicon	0·50	1·0 max.	0·51	1·0
Manganese	0·70	1·0 max.	1·38	0·8
Nickel ..	72	Bal.	15·48	13·0
Chromium	15	20	12·48	13·0
Molybdenum	—	—	2·74	2·0
Iron ..	7	5·0 max.	Bal.	—
Tungsten ..	—	—	0·77	2·5
Titanium ..	2·5	2·2	0·45	—
Aluminium	0·7	1·1	—	—
Niobium ..	1·0	—	—	3·0
Cobalt ..	—	2·0	—	10·0
Boron ..	—	—	0·11	—

'Very little information is available regarding the notch-sensitivity of austenitic alloys. From a figure given in the paper it is evident that while Inconel 'X' and Nimonic 80A are quite notch-sensitive at 1300° and 1400°F. (705° and 760°C.), 'recovery' has occurred at the preferred temperature of application (1500°F.: 815°C.). At this temperature the alloys would presumably not be weakened by notching, regardless of the time to failure. The boron-modified hot-cold-worked stainless steel, Haynes alloy 88, is very notch-sensitive at temperatures between 1200° and 1500°F. (650° and 815°C.). It is noted that SIEGFRIED found that the notch-sensitivity of G. 18B steel at 1200°F. (648°C.) was markedly increased by cold deformation. Additional results on this material, reported by the same author, indicate that in the solution-quenched condition it is notch-sensitive at 1200°F. (650°C.) and 1290°F. (700°C.).'

Notch-Tensile Properties of Nickel-Alloy Steels and High-Temperature Cobalt-Nickel-Chromium-base Alloys

See abstract on p. 191.

Inter-Relation of Composition, Structure and High-Temperature Properties of Iron-Chromium-Cobalt-Nickel Alloys

J. D. NISBET and W. R. HIBBARD: 'A Rationalization of Measured High-Temperature Properties of Fe-Cr-Co-Ni Alloys.' *Jnl. of Metals*, 1953, vol. 5, Sept., Sect. 2; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1149-65: T.P. 3618E.

During the past few years the basis of high-temperature austenitic alloys has gradually been changed from iron-rich to nickel-rich and cobalt-rich compositions, and recently much interest has been shown in iron-cobalt-nickel-chromium alloys having an approximately constant chromium content of 20 per cent. Concurrently, research has been carried out on the hardening influence and other effects of addition elements which have relatively low solubility in the quaternary base. In this connexion the modifications made have ranged from addition of a single element to varying combinations of molybdenum, tungsten, niobium, carbon, titanium and aluminium.

In order to arrive at a more fundamental understanding of the inherent characteristics of both the quaternary alloy base and of the modified alloys developed from it, research was initiated (in 1946) in the laboratories of the General Electric Company, Schenectady, with two main objects: determination of (1) the effect of composition upon the mechanical properties of face-centred cubic iron-nickel-cobalt-chromium alloys, and (2) the effect, on mechanical properties, of adding various compounds of different composition and characteristics, to various f.c.c. solid solutions. Part one of the investigation was based on examination of more than two hundred alloys, consisting of binary, ternary and quaternary combinations of iron, chromium, cobalt, and nickel: part two covered study of twelve modifying additions: tungsten, tantalum, molybdenum, niobium, titanium, zirconium, vanadium, beryllium, aluminium, carbon, oxygen, nitrogen.

The present paper contains a large amount of experimental data relating to high-temperature properties and structure of typical alloys within the two groups. The authors give the following summary of their conclusions:—

'The strength of these alloys can be rationalized on the basis of strengthening effects related to fundamental characteristics of the components and their possible phasial relationships.

'Nickel-rich solid solutions are hardened more effectively by chromium than by cobalt, or iron. Solute additions are not mutually independent, but interaction effects, generally positive for cobalt and negative for iron, indicate that variations in base composition require quantitative compensation to maintain a given strength.

'Several factors influence ductility, including alloy content, crystal structure, temperature at which fracture changes, temperature-dependence of precipitation-hardening, temperature of allotropic transformation, deoxidation practice, recovery, and recrystallization.

'In the design of alloys for high-temperature applications, it appears that the characteristics of the base alloy should include: (*a*) Solid solutions as nearly as possible saturated at the temperatures of maximum solubility with the most potent solution-hardening elements (i.e., large differences in atom diameter, valency, compressibility, and minimum solubilities); (*b*) the most complex structures consistent with acceptable ductility; (*c*) the highest melting alloys, preferably for service at temperatures $<0{\cdot}5$ melting temperature. Since solution-hardened alloys are usually lower melting unless they form peritectics, and since complex structures are not readily fabricated, the optimum compromise between all of these factors should be sought. In seeking this compromise, it should be remembered that solution-hardening elements, in addition to raising the base strength, also increase the amount of strain-hardening and raise the recrystallization temperature. These factors in part counteract the lowering of the melting point.

'The relative strengthening effects of various incongruous* additions appear to be related to the melting point of the incongruous addition, to the difference in atom diameter between the incongruous addition and the base, and probably to the compressibility. The high melting point of the incongruous addition probably reflects itself in the melting point of the compound formed during age-hardening. This effect was particularly apparent in the simultaneous additions of carbon and titanium or tantalum, which formed high-melting carbides and produced the largest amount of strengthening found.

'A limited amount of data on simultaneous additions of carbon and titanium or tantalum suggests that when the incongruous elements have large interaction effects their strengthening effect upon a base will be considerably different from that obtained from individual elements.

'It was found that several of the alloy additions had purifying effects on the base, as indicated by lowering of the base strengths.'

Effect of Alloying Elements on Creep of Nickel

See abstract on p. 183.

Influence of Boron on Oxidation-Resistance of Chromium-Nickel-Cobalt-Iron Alloys

W. O. BINDER and E. D. WEISERT: 'Some Notes on the Oxidation-Resistance of Boron-containing Chromium-Nickel-Cobalt-Iron Alloys.' *Corrosion*, 1953, vol. 9, Sept., pp. 329-32.

Full form of paper reported, from abstract source, in *Nickel Bulletin*, 1953, vol. 26, No. 4, p. 59, *q.v.* In addition to the conclusions summarized from the abstract, it is noted that the authors recommend, in association with low iron and the use of tungsten rather than molybdenum as a strengthener, avoidance of high cobalt contents. Preferably, excessive use of cobalt should be obviated by higher nickel. Basis compositions of types so balanced are believed to increase oxidation-resistance by favouring the presence of the protective Cr_2O_3 type of oxide and by inhibiting formation of complex spinels and tungstates.

*Elements having relatively low solubility in the solid-solution base.

Materials for Aircraft Gas Turbines

R. B. JOHNSON: 'Jet Engine Metallurgy.' *Soc. Automotive Engineers, Preprint*, Feb., 1953; 12 pp.

The paper is based on the experience of the General Electric Company of U.S.A., in construction of production aircraft jet engines. It contains a critical discussion of the conditions which have to be satisfied to ensure good service performance of the respective components of jet engines, and records experience with the use of individual types of materials for such parts. Some methods which have been devised to obviate specific forms of defect or failure are discussed.

Nickel-Chromium Alloy Coating of Parts of Upsetting Machine

'An Unusual Application of Brightray Coating.' *Machinery (Lond.)*, 1935, vol. 83, Oct. 2, p. 662

Some years ago Bristol Aeroplane Company, Ltd. pioneered the use of Brightray (80–20 nickel-chromium alloy) for coating aero-engine exhaust valves, to protect the heads against deterioration in high-temperature service involving attack by leaded fuel. Similar treatment has also been applied, with much success, to the exhaust valves of motor vehicles.

Brightray coating has more recently been employed, by Bristol Aeroplane Company, for the coating of anvils in an electrical upsetting machine producing gas-turbine compressor blades. In this operation the temperatures reached are above 1000°C., a condition which, in conjunction with the pressure applied in forming, involves considerable strain of the anvil material. Various materials have been tried for the anvils, but even with tungsten steel cracking occurred after very short periods of service. The difficulty has been overcome by treating them with a coating of Brightray, applied by oxy-acetylene welding and finish ground. Steel anvils so treated give much longer life than those made from materials previously used, and when the surface has become slightly damaged in use the anvil can be re-ground and put back into service.

Low-Temperature Properties of Steels

See abstract on p. 192.

Grinding and Polishing of Nickel-Chromium Stainless Steels

'Surface Finishing Stainless Steel.' *Steel*, 1953, vol. 133, Aug. 24, pp. 82–3.

Brief, well illustrated survey of Armco Steel Company's practice in grinding and polishing, giving particulars of abrasives, lubricants, wheels, speeds, etc.

Stainless Steel in Ice-Cream Plant

'Ice-Cream Cold Store and Manufacturing Plant.' *Engineering*, 1953, vol. 176, Oct. 16, pp. 502–4.

Illustrated description of the London ice-cream plant of Messrs. T. Wall & Sons, Ltd. Stainless-steel equipment is extensively used, e.g., for the 300-gallon tanks in which the raw materials are blended, for piping through which the blended substance is conveyed to stainless-steel pasteurizers, for tanks in which the processed mixture is stored, and for other parts with which the ice-cream is in contact.

Metallic Materials for Surgical Use: Test Method

E. G. C. CLARKE and J. HICKMAN: 'An Investigation into the Correlation between the Electrical Potentials of Metals and their Behaviour in Biological Fluids.' *Jnl. Bone and Joint Surgery*, 1953, vol. 35B, Aug., pp. 467–73.

The authors review the literature dealing with the reactions of tissues with metals, and give details of an *in vitro* screening test designed to narrow the range of metallic materials worth testing *in vivo*. The procedure consists in determining, by a procedure which is described in the paper, a characteristic designated A.B.E. (anodic back e.m.f.), the significance of which is discussed. Correlation between A.B.E. and loss of weight due to corrosion, using equine serum, is demonstrated, and the inertness of eighty-seven metals and alloys is classified on the basis of the test proposed. The materials tested include nickel and a large number of nickel-containing alloys. It is emphasized that the results now published are based on *in vitro* tests only. *In vivo* experiments are in hand. Preliminary work suggests that there is some correlation between A.B.E. and the behaviour of metals in tissue.

Welded Stainless Steel High-Pressure Flasks

A. GRODNER: 'All-Welded Stainless Steel Flasks Operate at Pressures up to 3,000 p.s.i.' *Industry and Welding*, 1953, vol. 26, May, pp. 54–5.

This article contains short notes, diagrammatically illustrated, on methods used in production of stainless nickel-chromium-molybdenum steel high-pressure flasks (over 6 ft. long and having a 15-in. inside diameter) designed for operation at a pressure of 3,000 p.s.i. and at 100°F.

The cylinders are made from 1½-in. plate of niobium-stabilized type 347 steel, in two half lengths, with a circumferential weld seam at the centre. They are closed at the ends by 4½-in. thick solid stainless-steel heads, welded into place.

The first bead of each seam is examined with a fluorescent dye penetrant, to detect any surface cracks which might introduce slag into the interior of the flasks, and at intervals during the subsequent welding X-ray examination is made of the seam, to ensure that it is in every respect satisfactory. The heads, after machining and polishing, are welded into the cylinder ends, metal-to-metal contact being ensured by fitting the heads against backing-up rings previously welded into the cylinder. The interior of the flasks is cleaned to a 'surgical' degree of cleanliness, and during stress-relief heat-treatment furnace atmosphere is excluded by a continuous flow of hydrogen, to prevent formation of oxide films or the deposition of other foreign substances. As a further precaution against contamination of the interior of

the flasks, final hydrostatic testing, at 4,500 p.s.i., is done by the use of distilled water, followed by immediate drying of the interior surfaces by the application of external heat.

Corronel B: Properties and Applications

'The Properties and Applications of Corronel B.' *Reprint from Industrial Chemist*, 1953, vol. 29, Sept., pp. 397-9. Issued by Mond Nickel Co., Ltd.

This article gives a detailed account of the wrought nickel-molybdenum-base alloy to which reference was made in *Nickel Bulletin*, 1953, vol. 26, Nos. 8-9, p. 156.

Particulars are given of (1) the physical and mechanical properties of the alloy, (2) its resistance to corrosion, by hydrochloric, phosphoric and sulphuric acids, and other corroding media, and (3) methods suitable for hot- and cold-working, machining, annealing, and welding.

Typical industrial applications include many forms of equipment used in the general chemical industry, the petroleum industry, and other industries in which corrosives have to be handled. Details are given of the forms in which the wrought nickel-molybdenum alloy is available.

Lead-Free Paints for Marking High-Nickel Alloys

See abstract on p. 189.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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